COTTON WILT AND ROOT-KNOT

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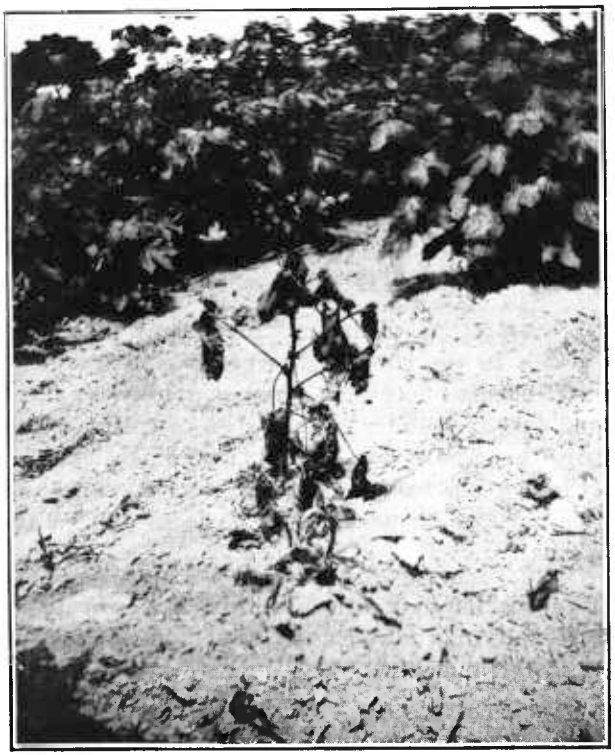

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COTTON WILT causes large preventable losses in the sandy soils of the cotton belt. Where root-knot also occurs, the injury is still greater.

Wilt is caused by a soil-inhabiting fungus which plugs the water vessels in the stem of the plant. No treatment with fungicides, fertilizers, or any material applied to the soil or the plant will prevent it; but varieties of cotton which resist the disease have been developed by breeding and can be obtained through purchase from cooperators of the Department of Agriculture, whose names may be learned from the local county agent.

Root-knot is due to an eelworm which is a parasite on many crops. It can be controlled by the crop-rotation methods outlined in this bulletin.

COTTON WILT AND ROOT-KNOT.

CONTENTS.

DISTRIBUTION OF COTTON WILT AND ROOT-KNOT.

THROUGHOUT the sandy sections of the cotton belt, where cotton wilt and root-knot occur every year to an increasing extent, there is urgent need for a fuller understanding of these diseases and the important relation they bear to each other and to the farmer's margin of profit. Wilt occurring alone causes serious loss to the cotton crop, not only by killing large numbers of plants, but, further, by stunting very many others and thus greatly reducing the yield. Cotton root-knot by itself causes a dwarfing of the plants and a consequent decrease in yield over large areas. Often the farmer does not notice this or attributes it to an unfavorable season, poor soil, lack of proper fertilization, or some local condition. Where these two diseases occur together, which is frequently the case, the loss is often so great that it becomes well-nigh impossible by the usual methods of cultivation to grow the principal money crop of this section without an actual loss. In other words, wilt and root-knot then become the most important limiting factors in the production of cotton. To remedy this condition, the whole scheme of farming must often be changed and planned with special reference to the control of these highly important enemies of the cotton crop.

Rotation of crops for the control of root-knot and the use of varieties of cotton resistant to wilt are more essential to the profitable growing of the crop in badly diseased areas than fertilization or cultivation, although these are of prime importance.

Cotton wilt and root-knot occur to a greater or less extent in every cotton-producing State from North Carolina to Texas. The areas where wilt is of most general and serious occurrence are southern and eastern South Carolina, southwestern Georgia, and southeastern Alabama. The lines and dots on the accompanying map (fig. 1)

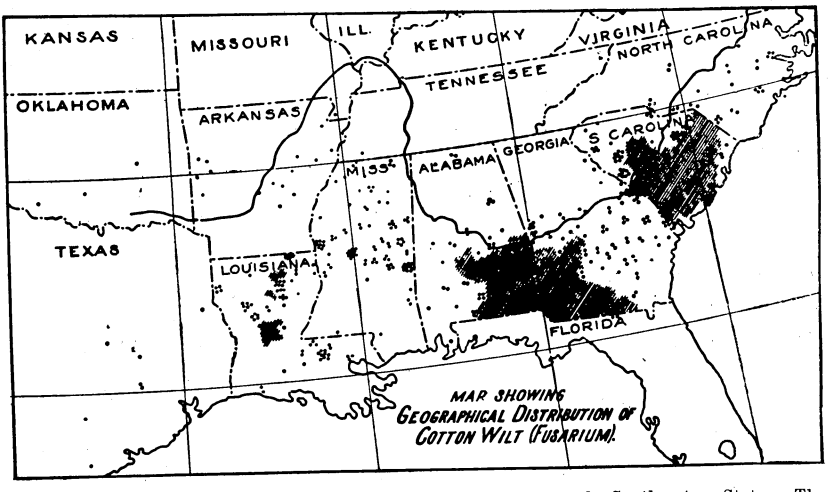

FIG. 1.—Map showing the geographical distribution of cotton wilt in the Southeastern States. The shaded portions show where the wilt is general, while the dots indicate scattered localities where the disease is known to occur.

show graphically the relative severity of wilt in the States where it occurs. Parallel lines indicate sections where the disease is known to be general, while dots are used to mark territory less generally infected, each dot indicating a place where the disease is known to occur. The heavy line marks the approximate boundary between the sandy and alluvial soils of the Coastal Plain, where wilt and root-knot are most prevalent, and the clay soils of the Piedmont Plateau, where the occurrence of these diseases is rare. Wilt without doubt exists in many places of which we have no authentic record, and it is rapidly spreading to new territory. It is probable that the disease will eventually be found in nearly all the cotton sections having sandy soils. Root-knot occurs even more generally than wilt in the same areas and soil types. Wherever sandy soils occur in the cotton belt root-knot is to be looked for.

Though it is difficult to form a very accurate estimate of the damage caused by these diseases, an estimate based on a farm-to-farm survey of a typical county indicates that root-knot of cotton alone causes a loss of $35,000,000 a year. The loss is occasioned not only by the death or dwarfing of affected plants, but by the lowering of the market value of infested land, by the increased cost of cultivation of such land, due to the growth of weeds where the cotton has died, and by the fact that badly diseased fields must often be used for crops less profitable than cotton. This situation is the more unfortunate because it is for the most part unnecessary. These diseases can be almost entirely controlled by the methods described in this bulletin.

HOW TO RECOGNIZE COTTON WILT.

When the leaves of cotton plants wilt and fall without any apparent reason, black-root, or wilt, is to be suspected. If a freshly wilted plant is examined (see title-page) and the interior of the stem or root is found to be browned or blackened (fig. 2), the disease is almost sure to be wilt. Certain kinds of dwarfing of the main stem are likewise characteristic of wilt, particularly a reduction in the length and a shortening of the distance between the branches. This is often accompanied by the normal development of one or more of the basal limbs, due to partial infection (fig. 3). The disease may kill the plants in early May, or its first indication may be the sudden wilting and death of practically mature plants in mid-September. All through the season, affected stalks die from the trouble. The first appearance of wilt in a field is usually in small rounded or irregular areas which enlarge each season. Outside the spots where the plants are killed, dwarfed and sickly plants occur, which may survive and produce a small crop. Occasionally plants are found that remain alive in the worst infected areas. By selection from such resistant plants varieties largely immune to the disease have been developed.

HOW TO RECOGNIZE COTTON ROOT-KNOT.

The detection of cotton plants affected by root-knot, except by an examination of the roots, is much more difficult than in the case of wilt. Diseased plants are distinctly stunted but not appreciably deformed, as in wilt, and both leaves and stem have a peculiar sickly yellowish green color. In times of drought, affected plants are

FIG. 2.—Oblique section of a wilt-diseased cotton stem, showing the browning caused by the wilt fungus.

FIG. 3.—A wilt-diseased cotton plant, showing the typical stunting of the main stem and the normal development of one lateral branch.

FIG. 4.—Root-knot on a cotton plant grown on land where nonresistant cowpeas were raised the previous year.

the first to show the lack of water and may wilt slightly in the middle of the day. If such a plant is pulled carefully or, better, dug up with a shovel, the roots will be found to be covered with swellings, or galls, from the size of a pinhead to half an inch or more in diameter, as shown in figure 4. If one of these knots is broken open, numerous pearly white rounded bodies about half the size of a small pinhead, the female nematodes (see fig. 7), can often be seen with the naked eye.

When root-knot occurs with wilt, which is often the case, the symptoms of both diseases are present. The plants usually all die or are so badly dwarfed that little or no cotton is produced.

IMPORTANT FACTS ABOUT COTTON WILT.

WILT CAUSED BY A FUNGUS.

Wilt is caused by a fungus, a minute moldlike plant growth, which enters the roots from the soil. It grows vigorously in the water-carrying vessels of the roots and stems, causing them to turn black. (See fig. 2.) It shuts off wholly or in part the water supply of the plant and eventually brings about the death of those badly affected. This fungus produces in great numbers several types of fruiting bodies, by which it is propagated.

Closely related fungi of the same genus cause serious wilts of okra, coffeeweed, cowpea, tomato, watermelon, potato, and other plants. Thus far these diseases have not been proved to be communicable to cotton.

WILT SPREAD BY NUMEROUS AGENCIES.

Wilt is spread by the direct growth of the causal fungus through the soil and by any agency which will transfer spores or disease-infected soil from one field to another, such as cultivators, plows, and other tools, the feet of men or animals, wind, and drainage water. During heavy rains, the overflow from diseased fields will carry the

wilt to lower areas. To prevent this, terraces may often be built advantageously to turn the water into ditches. Stable manure and the compost heap may be infected by soil from the feet of mules used in a diseased field, and thus the wilt may be carried to new areas. The disease is often spread most noticeably along frequently traveled farm roads or paths. Tests covering a period of four years to determine whether wilt is carried by the seed have given negative results.

WILT MOST SEVERE ON SANDY LAND.

Wilt occurs almost exclusively on soils of a sandy or sandy-loam nature. In most cases, the lighter the soil the more severe is the wilt. For this reason it is often worst in portions of the field where large quantities of sand have been washed by drainage water. Sandy ridges through the field or high sandy spots are also severely affected. Rarely has the disease been known to occur on clay soils, and then only when they were adjacent to infected sandy soils.

WET SEASONS FAVOR WILT.

It is a fact recognized by most farmers in wilt territory that the disease is more severe in wet seasons and less injurious in dry years. Abundant soil moisture favors a rapid growth of the cotton plant and likewise furnishes the best conditions for the development of the fungus. For this reason also, new cases of wilt are usually most numerous just after a rain.

ROOT-KNOT MAKES WILT WORSE.

When root-knot occurs with wilt, the amount of loss is very materially increased, and different methods of control are made necessary. Cotton is moderately subject to root-knot, which reduces the yield in hundreds of fields whose owners are ignorant of its presence. The plant illustrated in figure 4 shows a typical severe case of root-knot on cotton. The wounds which the nematodes make in the roots furnish points of entrance for the wilt fungus, which then completes the destructive work. Whole fields are thus practically annihilated, the farmer losing not only the crop but all the labor of planting and caring for it, when by the use of proper rotations a paying crop could have been grown. Even the wilt-resistant varieties bred by the Department of Agriculture are not entirely resistant to root-knot and should not be planted on land infested by nematodes until such fields have been rotated to reduce the number of these eelworms. In almost every case where wilt-resistant cotton sent out by the Bureau of Plant Industry was reported to have failed, the reason was found to be the presence of root-knot.

MEASURES FOR THE CONTROL OF COTTON WILT.

LATE PLANTING GIVES NO RELIEF.

Carefully conducted experiments have shown that late-planted cotton is as severely attacked by wilt as that put in at the usual time. Furthermore, it is a commonly accepted fact that late-planted crops seldom produce as large a yield as those planted early. In boll-weevil territory, cotton must be planted early to get ahead of the weevil.

FERTILIZERS AND FUNGICIDES INEFFECTIVE.

Cotton wilt can not be controlled by the use of fertilizers. Neither kainit, acid phosphate, salt, lime, potash, nitrate of soda, or any other fertilizer used alone or in combination has given any relief. In some cases of slight infestation the use of stable manure has been of benefit, and its use in the breeding of wilt-resistant varieties has been found of assistance.

The use of soil fungicides is too expensive to be worthy of consideration. Moreover, large quantities of numerous fungicides have been used on wilt-infected land without reducing the amount of the disease.

ROTATION OF CROPS IMPORTANT.

The fact that the wilt fungus can live for a long time as a saprophyte on the decaying organic matter in the soil renders it well-nigh impossible to starve out the disease by crop rotation. Short rotations are of little benefit. While rotations of seven to ten years have reduced the wilt somewhat, no case is known where it has been wholly eradicated. On the other hand, root-knot can be controlled by rotation.

FIG. 5.—A field of Upland cotton in South Carolina destroyed by wilt.

FIG. 6.—Dillon wilt-resistant cotton grown two years later on the badly infected field shown in figure 5.

Because of the almost universal occurrence of root-knot with wilt and because of the fact that nematodes increase the severity of wilt, rotation of crops, combined with the use of resistant varieties, becomes of vital importance in the control of wilt.

WILT CONTROLLED BY GROWING RESISTANT VARIETIES.

Wilt when occurring alone can be successfully controlled by the use of wilt-resistant varieties of cotton (figs. 5 and 6). When root-knot occurs with wilt, crop rotation must be combined with the planting of resistant varieties. Thousands of acres of these varieties have been profitably grown on wilt-infected land every season for the last eight or ten years. Their use on diseased land has long since passed the experimental stage, and each season sees the extension of their planting to new territory.

IMPORTANT FACTS ABOUT ROOT-KNOT.

ROOT-KNOT CAUSED BY EELWORMS.

Root-knot of cotton and other crops is caused by minute eelworms, or nematodes, which bore into the roots and live there. The irritation of their presence results in the formation of irregular swellings, or galls, varying in size from tiny enlargements on the small roots to knots an inch or more in diameter on the large ones. The male worms are too small to be seen with the naked eye, but the females (fig. 7) when full of eggs assume a spherical shape and may often be distinguished in freshly broken roots as glistening pearly bodies half the size of a small pinhead. Each female may lay several hundred eggs, and thus the worms are propagated.

HOW ROOT-KNOT IS SPREAD.

Root-knot may be carried from one field to another by any agency which will transfer some of the nematodes or their eggs, in exactly the same manner that wilt is disseminated. Drainage water is perhaps one of the most important means of spreading root-knot. In addition, a common agency for the introduction of the nematode into new territory is nursery stock. Seedling pecans, peaches, figs, mulberries, or pomegranates, and young asparagus, cabbage, eggplant, strawberry, tobacco, and tomato plants purchased from infested sections may carry the worms in their roots or in the soil adhering to them. Several cases have come to the notice of the writer which have been unquestionably traced to nursery-stock importations. In the West, where the nematode occurs quite commonly on the potato, the worms are carried in the tubers.

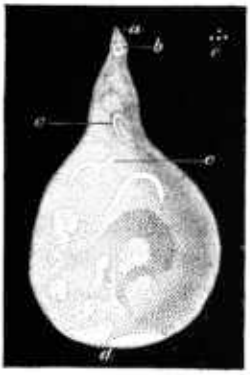

FIG. 7.—Female of the nematode gallworm (*Heterodera radicicola*), magnified 85 diameters: *a*, Mouth; *b*, spherical sucking bulb; *c*, *c*, ovaries, as seen through the body wall; *d*, anus; *e*, small white spots showing approximately the natural size of these worms. They are usually white. It is generally not difficult to isolate them in water by breaking open the galls containing them. (After N. A. Cobb.)

SANDY SOILS MOST SUBJECT TO ROOT-KNOT.

Root-knot is essentially a disease of light soils. Although the disease may occur on heavier soils than wilt, yet it is not, as a rule, serious on soils containing a large proportion of clay. In general, the lighter the soil the more severe the root-knot injury The places of greatest damage are usually light sandy spots or ridges in infected fields. In gardens which have been highly fertilized with stable manure root-knot is often very severe.

ROOT-KNOT ATTACKS MANY FARM CROPS.

Unlike wilt, root-knot attacks a very large number of plants, many of which are important farm crops. Those subject to root-knot injury may be divided into two groups, according to their degree of susceptibility. Some of the crops most severely attacked by root-knot are as follows:

Bean, soy.
Bean, Lima.
Beet.
Cantaloupe.
Carrot.
Celery.
Clover, bur.
Clover, crimson.
Cowpea (all varieties except Iron, Brabham, and Monetta).
Cucumber.
Eggplant.
Fig.
Lettuce.
Okra.
Peach.
Pecan.
Pomegranate.
Potato.
Salsify.
Squash
Tobacco
Tomato.
Watermelon.

The manner in which the roots of the cantaloupe and Black cowpea are covered with swellings, or galls, by the disease is shown in figures 8 and 9.

Plants less severely injured by root-knot are the following:

Alfalfa.
Asparagus.
Bean, snap.
Cabbage.
Clover, sweet.
Collard.
Cotton.
Mulberry.
Onion.
Pea, garden.
Potato, sweet.
Radish.
Spinach.
Strawberry.
Sugar cane.
Vetch, common.
Vetch, hairy.

A few common weeds are subject to nematode injury and should therefore be eradicated where the attempt is being made to reduce root-knot in fields. The most severely injured are the balloon vine, the maypop or passion flower, and the papaya or melon pawpaw. Weeds less severely affected by root-knot are mayweed, purslane, and sweet fennel.

FIG. 8.—Root-knot on cantaloupe.

SOME FARM CROPS RESISTANT TO ROOT-KNOT.

Fortunately, a few farm crops are largely or entirely immune to root-knot. By employing these in suitable rotations, nematodes may be starved out on infested fields, so that susceptible crops can be grown until the worms increase sufficiently to cause damage, when another rotation is necessary.

The following crops are largely or entirely immune to root-knot:

Barley.
Bean, velvet.
Beggarweed, Florida.
Chufas.
Corn.
Cowpea, Brabham.
Cowpea, Iron.
Cowpea, Monetta.
Grass, Bermuda.
Grass, crab.
Grasses (nearly all).
Kafir.
Millets (nearly all).
Milo.
Oats, winter.
Peanut.
Rye.
Sorghum.
Wheat.

ROOT-KNOT INCREASED BY MOST VARIETIES OF COWPEAS.

Such varieties of cowpeas as the Whippoorwill, Clay, Black, Unknown, Red Ripper, New Era, and others are so susceptible to root-knot that not only are they seriously injured, but the growing of them on nematode-infested fields greatly increases the number of worms in the soil, and consequently the damage to subsequent cotton or other susceptible crops. It is a common complaint of farmers in wilt sections that the wilt is noticeably more severe after a crop of cowpeas of a variety which is susceptible to root-knot. This is due to the fact that the nematodes make points of entrance for the wilt fungus, which then kills or further injures the plants. A few varieties of cowpeas are highly resistant to nematodes, including the Iron, Brabham, and Monetta. These should be the only cowpeas planted on land infested with root-knot.

FIG. 9.—Root-knot on Black cowpea.

MEASURES FOR THE CONTROL OF ROOT-KNOT.

ROOT-KNOT CONTROLLED BY CROP ROTATION.

The rotation and diversification of crops are of fundamental importance to southern agriculture everywhere and become absolutely necessary where the root-knot nematode is present.

It has been repeatedly demonstrated by many farmers that root-knot can be controlled by the use of proper crop rotations. The principles on which such rotations are based are (1) the use of crops immune to nematode attacks until the nematodes are sufficiently reduced so that susceptible crops may be profitably grown and (2) the eradication of all weeds subject to root-knot. The use of crops that will return a profit and the building up of the fertility of the soil are also important considerations. Every farmer must work out for himself the particular rotations suited to his farm and his type of farming.

If land is very badly infested with nematodes as well as wilt, a 2-year or 3-year rotation with immune crops is recommended before susceptible crops, including cotton, are grown, and they should not

be grown for more than one or two years thereafter before the rotation with immune crops should be repeated. When the infestation is less severe, a 1-year or 2-year rotation will do much to put the land in condition to grow the crops desired.

In planning rotations for land infested with root-knot, susceptible crops, such as tobacco, sweet potatoes, cotton, cantaloupes, okra, and tomatoes should never follow one another. The damage increases each year so long as susceptible crops are planted. If the first crop should escape serious injury, the nematodes will increase in the soil to such an extent that the second crop will be almost sure to show a decided loss. Immune crops should always be alternated with susceptible ones and the nematode injury thereby reduced to a minimum.

With regard to winter legumes, such as crimson clover, bur clover, Japan clover, and the vetches, the use of which is rapidly increasing throughout the South, sufficient observations have not yet been made to warrant any general statement. These plants are listed as moderately to severely attacked by root-knot, but the nematodes are not very active during the period between October 15 and April 15, when these crops are usually grown, and they may therefore escape serious injury.

BEST ROTATIONS TO USE.

While no recommendations can be given that will apply to all situations and soil types, a typical rotation that can be modified to fit any condition is suggested. For land infested with both wilt and root-knot the following treatment has been successfully used by many armers: Beginning in the fall, sow winter oats if they can be gotten in early enough to make a fairly good growth before it is necessary to plow the land for the next crop. Plow the oats under for green manure and plant corn with Iron, Brabham, or Monetta cowpeas between the rows, putting in the corn at the usual time, about March 15 to 20 for middle Georgia and South Carolina. In the fall sow a winter grain; this can be cut for hay or allowed to ripen. Cowpeas, either the Iron, Brabham, or Monetta variety, may then be broadcasted or, better, planted in 2-foot drills, where they can be cultivated once or twice. The cowpeas may be saved for seed or cut for hay and followed by another crop of winter grain. This should be plowed under in the spring in time to plant a wilt-resistant variety of cotton the third year. Wheat, rye, or barley may be substituted for oats as a winter-grain crop, and velvet beans for the cowpeas in the more southern districts. Any of the other immune crops included in the list on page 11 may be used in the rotation.

Considerable reduction in the nematode injury will follow the use of a 1-year rotation composed of two winter-grain crops with a crop of velvet beans or resistant cowpeas grown the intervening summer.

In one case in Georgia, the growing of a single crop of Iron cowpeas on wilt and nematode infested land, where 75 per cent of the previous cotton crop was killed, resulted in a reduction of the loss in the cotton crop the succeeding year to less than 10 per cent, as against a loss of 90 per cent on adjoining land planted the previous year in cotton instead of Iron cowpeas. When the injury is as severe as this, however, it is usually more profitable to practice a 2-year or 3-year rotation.

WILT-RESISTANT VARIETIES DEVELOPED BY BREEDING.

The commercial varieties of cotton differ considerably in their susceptibility to wilt, but none of them are sufficiently resistant to be grown profitably on wilt-infected land. As the result of many tests it has been found that the large-bolled cottons, such as the Russell, Cleveland, Cook, and Triumph, are in general more subject to wilt than other groups. Some of the smaller bolled varieties have shown considerable resistance and have been used as a basis for the breeding of resistant strains. Some, however, are very susceptible.

The experiments of the Bureau of Plant Industry, which have now been carried on for 18 consecutive years, have shown that the only practicable solution of the wilt problem is through the use of wilt-resistant strains developed by special breeding. Such cottons have been produced and grown successfully for the past 10 or more years on thousands of acres of wilt-infected land in a large number of localities, until no doubt remains as to the possibility and practicability of controlling the disease in this way. During this period these varieties have been further improved by selection for greater resistance, larger yield, longer lint, higher percentage of lint, and other desirable qualities.

The development of wilt-resistant strains requires breeding for several years by the careful methods described later in this bulletin. Mass selections from apparently resistant strains of existing commercial varieties will not suffice. The selection of apparently resistant plants from the varieties usually grown may occasionally lead to the development of a resistant variety, but will generally result in disappointment. Only by the selection of resistant plants from an inherently resistant strain, by the subsequent testing of these on wilt-infected land, and by the continuation of individual selections and progeny-row tests can a resistant variety be developed.

DILLON.

The first wilt-resistant Upland cotton produced was the Dillon, a limbless cluster variety derived from the old Jackson Limbless. It is very productive on land to which it is adapted. Crops of a bale or more per acre have been grown where other varieties were a

failure. The yield of lint is 37 to 38 per cent. This cotton has been grown quite widely since its introduction in 1904 and is still highly resistant to wilt and root-knot. The fact that it is a cluster cotton and rather hard to pick has prevented its adoption by many farmers.

DIXIE.

The second wilt-resistant variety developed by the Department of Agriculture was the Dixie. This has the branched pyramidal habit of growth characteristic of the Peterkin group of varieties, and on this as well as other accounts has gained much wider popularity than the Dillon. The Dixie (fig. 10) had its origin in a selection made at Troy, Ala., of a plant presumably the result of an accidental cross between two of the numerous Upland varieties planted there in 1902. It has been carefully bred by the plant-to-row method until well fixed and has been considerably improved in earliness, size of boll, and percentage of lint.

FIG. 10.—Typical plant of Dixie wilt-resistant cotton.

The Dixie variety is now being grown very extensively throughout the wilt districts of Alabama, Georgia, and South Carolina, and is very largely displacing the Dillon.

A technical description of the Dixie variety follows:

Plant vigorous, wilt resistant, of medium height, pyramidal, nearly of the Peterkin type, usually with two or more large basal branches, and with long, slender, slightly drooping fruiting limbs; leaves of medium size; bolls of medium size, about 75 being required for a pound of seed cotton, easy to pick, seed small, weight of 100 seeds 10 grams, variable in color, but typically covered with short brownish white fuzz; lint full seven-eighths of an inch; percentage of lint to seed, 35 to 37.

HYBRID RESISTANT STRAINS.

When the boll weevils began their eastward advance toward the badly wilt-infected cotton areas of Alabama and Georgia, a new problem was presented, the production of a variety of cotton that

would be resistant to wilt and sufficiently early to be grown in the presence of the weevil. It was also desired to produce a cotton having larger bolls, longer lint, and a higher percentage of lint than either the Dixie or the Dillon variety. The indications are that both of these varieties, though medium early, are too late to be successfully grown where the boll weevil is present. Accordingly, in 1908, 1909, and 1911, a large number of hybrids were made between the Dillon and Dixie as wilt-resistant parents and several of the better large-bolled early varieties, some of which were being successfully grown in areas infested with the boll weevil, namely, the Triumph, Cook, Pride of Georgia, Columbia, Coker, Webber, Foster, and Trook.

The first of the hybrids have now been grown six years on wilt-infected land. Several promising types have been selected, which are very highly resistant to wilt, uniform, earlier than the Dixie, and possess to a greater or less degree the other characters desired of larger bolls, longer lint, and higher percentage of lint. There remains now the important work of testing these hybrids on wilt-infected land in the presence of the boll weevil, to determine which ones are best adapted to withstand the attacks of these two most serious enemies of the cotton industry. As soon as the tests are completed, the best strains will be propagated as rapidly as possible and their seed distributed.

OTHER RESISTANT VARIETIES.

Several promising wilt-resistant varieties have been bred by Mr. A. C. Lewis, of the Georgia State Board of Entomology, and are being introduced in Georgia.

Among the several so-called resistant varieties that have been developed by individual farmers, two are worthy of mention. The variety known as Sam Wood was developed by Judge Samuel Wood, of Abbeville, Ala., and has been grown to a considerable extent in Henry and adjoining counties of southeastern Alabama. The variety is tall, approaching the semicluster type, quite wilt resistant, productive, and gives 38 to 40 per cent of lint. Its principal faults are small bolls and short lint, great lack of uniformity, and late-maturing habit. It is probably too late for successful culture in the presence of the boll weevil.

Another variety has been developed in the same section by Mr. W. F. Covington, of Headland, Ala., and is known commercially as the Covington Toole wilt-resistant cotton. This is a selection from the Improved Toole. It possesses the earliness and productiveness of the Toole, together with its high percentage of lint, is very uniform, and fairly resistant to wilt. For those who do not object to small bolls, short lint, and lack of storm resistance, this variety will prove superior to other commercial varieties for wilt-infected land, especially in southeastern Alabama, to which section it seems best adapted.

RESISTANCE TO WILT MAINTAINED BY CAREFUL BREEDING.

Several years' experience with wilt-resistant varieties has demonstrated the fact that resistance to wilt can be maintained only by careful attention to breeding. Special care is needed to prevent the deterioration of resistant varieties through crossing with nonresistant cotton in near-by fields, through the lack of selection, and through the mixing of seed at the public gins. A careful man can maintain the resistance of his cotton indefinitely, but when neglected it loses this quality in three or four years and must be replaced by fresh seed. Consequently, there is likely to be a permanent annual demand for several thousand bushels of carefully bred wilt-resistant seed in nearly every infected county. It is important that this should be grown in the home county, as locally grown seed gives better results than seed brought from a distance. Because of these facts an excellent opportunity exists for progressive men in every wilt-infected county to engage with profit in the growing of seed of wilt-resistant varieties of cotton. The method found most successful requires care, accuracy, and instruction at the start.

PRINCIPLES OF BREEDING.

The careful farmer has heretofore attempted to maintain the quality of his cotton by planting his seed patch at a distance from other cotton to avoid crossing, by pulling out undesirable plants, by mass selection of the best plants in the field, and by care to avoid the mixing of the seed with that of other cotton at the gin. These are all important, but one additional step is necessary for the best results in breeding for wilt resistance, viz, the adoption of the plant-to-row method of selecting and testing plants. The increased value of the plant-to-row method of breeding, which is necessary to maintain wilt resistance, is based on the principle that individual plants differ not only in their visible characters but, what is more important, in their inherent power to transmit these characters to their progeny. Two plants growing side by side may be identical so far as the eye can see, both in external characters and apparent resistance to wilt. The resistance of one plant may be due to an inherent quality, which will be passed on through the seed to the offspring, while the apparent resistance of the other may be caused by lack of wilt infection. By planting the seed of these two plants in progeny rows on wilt-infected land it is possible to pick out and save the resistant row and discard the other. (Fig. 11.) If such plants are picked together, both the good and the bad qualities are perpetuated and progress is greatly hindered. The same principles apply to other characters. They are extremely important for general cotton breeding, but in breeding for wilt resistance they are absolutely essential.

BREEDING METHODS.

For the assistance and guidance of farmers who desire to take up the growing of wilt-resistant cotton seed, either for their own use or for sale, the methods worked out by the Bureau of Plant Industry as the result of 15 years' experience will be described.

Briefly, the plant-to-row method of breeding is as follows: Select the most resistant plants to be found, pick and gin them separately, plant a row from each on wilt-infected land, discard the nonresistant and inferior rows, and continue to select and breed from the best

FIG. 11.—Progeny rows in a breeding plat of Dillon cotton, each row from a single plant. The center row proved nonresistant. The parent plant was healthy, thus showing the necessity of progeny-row tests in the selection of resistant strains.

rows and plants only. The breeder must formulate a type of plant toward which to select and keep this always in mind.

SELECTION OF WILT-INFECTED LAND.

All breeding work for resistance to wilt must be done on wilt-infected land, so that nonresistant plants will be eliminated as rapidly as they appear and only resistant ones propagated. Land uniformly infected with wilt should be selected, as free as possible from root-knot, separated from other cotton to avoid cross-pollination, and near enough to the house to be convenient for selection work at odd times. The plat may be located in a cornfield or in a field of the same variety

of cotton. It should be rectangular in shape, with all the rows the same length, and prepared and fertilized as for other cotton. The rows should be laid off 4 to 4½ feet apart and the hills 2 to 2½ feet, to allow room for the normal development of plants.

PLANTING SELECTIONS IN PROGENY ROWS.

Plant 100 hills of each selection, four or five seeds to the hill, and save the remainder for replanting. Checkrow to get the hills evenly spaced, or stretch beside the row a cord with the distances indicated. Make a shallow trench with a small bull-tongue plow or make a depression with the heel. Drop the seed in this and cover it lightly with the foot. Drive a stout stake at the end of each row and write the selection number on it with a hard lead pencil. Make a diagram of the plat, recording the number and location of each row, as stakes are sometimes broken in cultivation.

THINNING AND PULLING OUT DISEASED PLANTS.

After replanting and when the cotton is all up, thin to one plant to the hill and record the number of plants left in each row. Under no circumstances replant with any other cotton. Go over the plat occasionally and pull out all diseased plants. In September, just before selections are to be made, count the healthy plants in each row. These counts compared with the stand counts will give the percentage of wilt resistance.

SELECTION OF THE BEST ROWS AND PLANTS.

Discard rows showing much wilt. Carefully compare the most resistant rows with regard to earliness, productiveness, uniformity, type, size of bolls, and length and quantity of lint, and save four to eight of the best rows. In the selection of rows as well as plants, wilt resistance is the first and most important consideration. Continuous selection toward a certain ideal type is also essential. Pick separately several of the best plants from each selected row, giving each its proper row number with the plant number added, thus, 18–1, 18–2, 18–3, and so on. Use tags for labeling plants and sacks. Selected plants should be free from anthracnose and other diseases.

MAKING CAREFUL NOTES.

Notebooks must be provided to record the data regarding the rows and plants. Make notes on the selected rows covering the points considered in the selection. Take notes on each selected plant covering the following points: Earliness, shape, height, and productiveness of plant, length of joints, shape and size of bolls, size and color of seed, and length, strength, and percentage of lint. A special 4 by 6 inch note blank with spaces provided for these notes in detail

has been devised and used by the Department of Agriculture in all of this breeding work. By the use of these blanks the time required to make the necessary notes has been greatly reduced. Neatness and legibility are important, and to this end a pen or hard lead pencil should be used, as notes taken with a soft pencil soon become rubbed and blurred. Notes should be entered directly in the notebook and not copied from memoranda.

GINNING THE SEPARATELY SELECTED ROWS AND PLANTS.

The ginning of the individual selections and progeny rows should be left until winter, when the rush of fall work is over. A small hand gin is most convenient for ginning individual plants. Three types of hand gins are on the market: (1) A small saw gin, very similar in appearance to the ordinary commercial saw gin, but having only 10 saws and furnished with a handle by means of which it is operated; (2) a small-sized roller gin of the type generally used to gin Sea Island cotton and also operated by a handle; and (3) a gin somewhat similar to the roller gin, but having a series of fingers instead of beaters to break the lint from the seed. The price of these gins ranges from $50 to $75. It is often possible for several farmers to club together to bear the expense of such an outfit. A single large saw gin can be used for row plats. In ginning different individual plants or progeny rows, great care should be taken to see that the gin is thoroughly cleaned out after each operation, so that not a single seed will be left to mix with the succeeding lots.

DETERMINING THE LENGTH AND PERCENTAGE OF LINT OF EACH PLANT AND ROW.

Weigh the seed cotton from each plant or row; gin and weigh the seed. Compute the percentage of lint by dividing the weight of lint by the weight of seed cotton. In the final selection of plants to be grown, give preference to those with high lint percentage. Determine the length by combing out the lint on a few seeds and measuring with a rule. Discard selections having lint that is less than three-fourths to seven-eighths of an inch long.

PLANTING THE BEST SELECTIONS AND ROWS.

When all the plants have been compared, pick out 25 to 50 of the selections made which have the longest and best percentage of lint and which conform most nearly in other characters to the type adopted. Plant these the next season in progeny rows, as already described. Save the best progeny rows and selections from them, as before.

Plant in increase plats the seed of the two or three best rows saved, dropping them by hand to make them go as far as possible. Save a few seeds for replanting and under no circumstances use any

other cotton seed for this purpose. The increase plats may well be planted immediately surrounding the progeny block. Thin to one plant in a place. Go over the plats several times row by row and pull out all wilted and off-type plants, to prevent their crossing with good plants. If very much wilt develops in any plat, discard it. Pick the increase plats by themselves, carefully sack and label the cotton, and put it away until the rush of the ginning season is past.

CARE IN GINNING.

To avoid every possibility of mixing with other seed, use a single gin, remove every seed from the roll, and do not pass the cotton through the usual suction chute, but feed by hand and catch the seed on a burlap sheet on the floor. Weigh the seed cotton and the seed from each plat and determine the lint percentage. Store the seed where there will be no danger of it being mixed with other seed.

PLANTING THE SEED FIELD FROM THE BEST INCREASE PLAT.

Use the seed from the increase plat showing the greatest wilt resistance, highest productiveness and percentage of lint, and other characters conforming most nearly to the adopted type for planting a seed field. Give this field the same care as the increase plats.

Beginning with the third year and each year thereafter, the farmer will have 25 to 50 progeny rows immediately surrounded by two to four increase plats and a large seed field from which seed can be sold or used for planting larger areas.

Careful personal supervision of the details of this work is essential for the maintenance of the best grade of seed.

COOPERATION WITH FARMERS BY THE DEPARTMENT OF AGRICULTURE AND THE STATE EXPERIMENT STATIONS.

The demand for wilt-resistant cotton seed became so great in 1910 that arrangements were made with a dozen farmers in South Carolina and Georgia to grow seed for sale under the supervision of the Department of Agriculture. This was a distinct success, but the demand for seed was greater than the supply. The work has since been still further enlarged through cooperative arrangements by the Bureau of Plant Industry in 1911 with the South Carolina Agricultural Experiment Station and the State Board of Entomology of Georgia, and in 1914 with the Alabama Agricultural Experiment Station.

PURPOSE OF THE WORK.

The purpose of this cooperative work is twofold: (1) To provide a definite and active means of carrying directly to the farmer facts regarding the nature of the wilt and root-knot of cotton and other crops and the best methods of controlling them and (2) to secure

the assistance of progressive farmers in all wilt-infected sections in the production of an adequate supply of resistant cotton and cowpea seed to meet the local demand, to maintain its quality, and to produce still better strains.

HOW THE WORK IS DONE.

In the dissemination of information about wilt and root-knot every available agency is utilized. A field pathologist, representing the Department of Agriculture and the State agency, visits all sections of the State where these diseases occur and gives lectures on them at farmers' institutes, at county and State fairs, at meetings of the agents of the Farmers' Cooperative Demonstration Work, and at other gatherings of farmers. The demonstration agents are very important means of getting information and advice to the farmer at first hand. It is therefore essential that they have a full and accurate understanding of all the details, so that correct advice may be given. From time to time the local newspapers are supplied with articles on these same subjects. Bulletins are also published by the Department of Agriculture and by the State agricultural experiment stations.

FARMERS BECOME COOPERATIVE BREEDERS.

Under the supervision of the field pathologists, about 50 farmers in the States of South Carolina, Georgia, and Alabama, are now growing wilt-resistant cotton seed for sale. These cooperative breeders agree to secure proper seed, to follow the breeding methods outlined by the field pathologist, to exercise necessary care to maintain the purity of their seed, and to offer it for sale at a reasonable price, not to exceed an amount previously agreed upon. They also agree not to sell seed not grown by them unless so stated.

The field pathologist, as a representative of the State and of the Department of Agriculture, provides these cooperative breeders with small quantities of select planting seed in the beginning or refers them to other breeders from whom they can purchase such seed at a reasonable price. He visits the breeders several times during the season to advise with them regarding the work and to show them all the details, from the planting through the roguing, selection, note taking, and ginning. He will also inspect the seed fields and give the breeders seed certificates.

SEED CERTIFICATES GIVEN.

In the early stages of the work it was not found advisable to start a system of seed certification, but such a system will eventually be put into practice. Under this plan two grades of seed are recognized, "registered seed" and "improved seed." By "registered seed" is

meant seed grown by the individual-selection and progeny-row methods described in this bulletin, which is found on inspection to be resistant and of the highest grade and purity. The term "improved seed" designates all other seed where the standard of the variety in wilt resistance, productiveness, and purity is being maintained, but where the plant-to-row method is not being followed in all of its details. The plan is to give certificates only after thorough inspection of the growing crop by the field pathologist and after an official test of the seed is made in comparison with standard resistant strains.

PUBLICATIONS OF THE UNITED STATES DEPARTMENT OF AGRICULTURE OF INTEREST IN CONNECTION WITH THIS BULLETIN.

AVAILABLE FOR FREE DISTRIBUTION BY THE DEPARTMENT.

Cotton Improvement Under Weevil Conditions. (Farmers' Bulletin 501.)
Cotton Anthracnose and How to Control It. (Farmers' Bulletin 555.)
Growing Egyptian Cotton in the Salt River Valley, Arizona. (Farmers' Bulletin 577.)
A New System of Cotton Culture and Its Application. (Farmers' Bulletin 601.)
The Red Spider on Cotton and How to Control It. (Farmers' Bulletin 735.)
Cotton Ginning Information for Farmers. (Farmers' Bulletin 764.)
Losses from Selling Cotton in the Seed. (Farmers' Bulletin 775.)
Sea Island Cotton. (Farmers' Bulletin 787.)
Classification of American Upland Cotton. (Farmers' Bulletin 802.)
The Boll-Weevil Problem with Special Reference to Means of Reducing Damage. (Farmers' Bulletin 848.)
Seed Selection of Egyptian Cotton. (Department Bulletin 38.)
Spinning Tests of Upland Long-Staple Cottons. (Department Bulletin 121.)
Economic Conditions in the Sea Island Cotton Industry. (Department Bulletin 146.)
Relation of the Arizona Wild Cotton Weevil to Cotton Planting in the Arid West. (Department Bulletin 233.)
The Handling and Marketing of the Arizona-Egyptian Cotton of the Salt River Valley. (Department Bulletin 311.)
Studies on the Biology of the Arizona Wild Cotton Weevil. (Department Bulletin 344.)
Studies of the Mexican Cotton Boll Weevil in the Mississippi Valley. (Department Bulletin 358.)
Comparative Spinning Tests of the Different Grades of Arizona-Egyptian with Sea Island and Sakellaridis Egyptian Cottons. (Department Bulletin 359.)
Disadvantages of Selling Cotton in the Seed. (Department Bulletin 375.)
Cotton Boll-Weevil Control in the Mississippi Delta, with Special Reference to Square Picking and Weevil Picking. (Department Bulletin 382.)

FOR SALE BY THE SUPERINTENDENT OF DOCUMENTS, GOVERNMENT PRINTING OFFICE, WASHINGTON, D. C.

The Cotton Boll Worm. (Farmers' Bulletin 29.) Price, 5 cents.
The Manuring of Cotton. (Farmers' Bulletin 48.) Price, 5 cents.
Building up a Run-Down Cotton Plantation. (Farmers' Bulletin 326.) Price, 5 cents.
A Profitable Cotton Farm. (Farmers' Bulletin 364.) Price, 5 cents.
The Boll Weevil Problem, with Special Reference to Means of Reducing Damages. (Farmers' Bulletin 512.) Price, 5 cents.
The Classification and Grading of Cotton. (Farmers' Bulletin 591.) Price, 5 cents.
Sea Island Cotton. (Farmers' Bulletin 787.) Price, 5 cents.
Tests of the Waste, Tensile Strength, and Bleaching Qualities of the Different Grades of Cotton as Standardized by the United States Government. (Department Bulletin 62.) Price, 5 cents.
Recent Studies of the Mexican Cotton Boll Weevil. (Department Bulletin 231.) Price, 5 cents.
Single-Stalk Cotton Culture at San Antonio. (Department Bulletin 279.) Price, 10 cents.
Lessons on Cotton for the Rural Common Schools. (Department Bulletin 294.) Price, 5 cents.
Cotton, the Greatest of Cash Crops. (Secretary's Circular 32.) Price, 5 cents.
The Control of Texas Root-Rot of Cotton. (Bureau of Plant Industry Bulletin 102, Part 5.) Price, 5 cents.

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